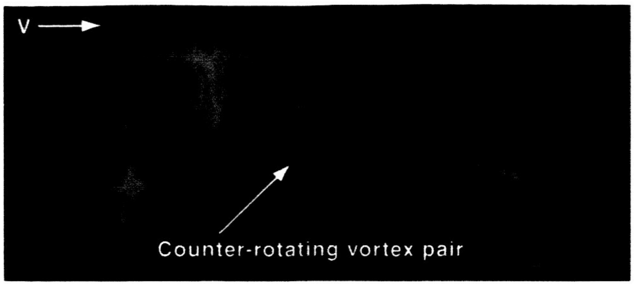

Fig. 1. Counter-rotating vortex pair for a blade-vortex interaction (BVI) test condition.

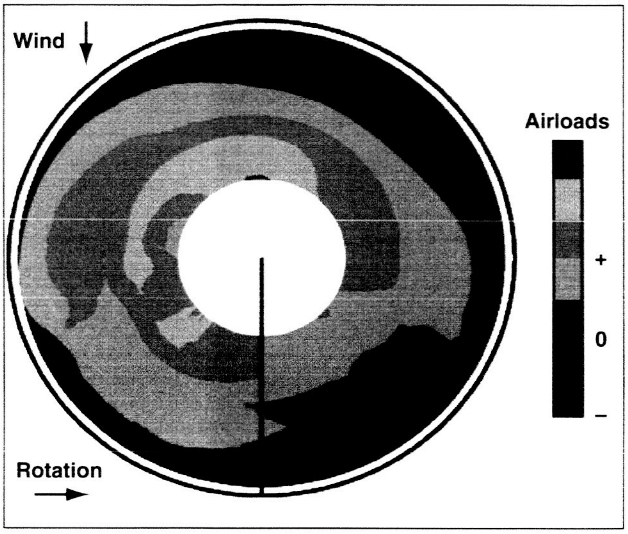

Fig. 2. Air-loads distribution for BVI condition.

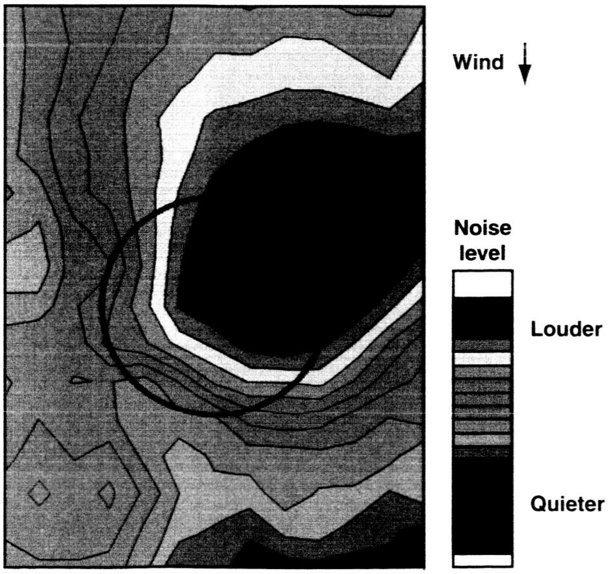

Fig. 3. BVI noise directivity map.

Single-Point and Multi-Point Aerodynamic Shape Optimization of a High Speed Civil Transport

Susan Cliff

The focus of this work was to develop and apply high-fidelity numerical design optimization techniques to the aerodynamic design of High Speed Civil Transport (HSCT) configurations for the purpose of substantially improving their aerodynamic performance, in an effort to develop an economically feasible concept. It was sponsored by the High Speed Research (HSR) program in direct support of Goal 2, Objective 6: "Reduce the travel time to the Far East and Europe by 50% within 20 years, …." A direct consequence of this effort was the rapid acceleration of the development of high-fidelity aerodynamic design optimization methods within NASA and industry, applicable to the entire spectrum of flight vehicles. Such methods represent the next generation of design tools and hence directly support Goal 2, Objective 8: "Provide next-generation design tools…."

Single-point and multi-point aerodynamic-shape optimization methods at Ames were developed and demonstrated for the design of an advanced HSCT referred to as the Technology Concept Airplane (TCA). A large variety of software methods were integrated to yield an efficient and productive design/optimization process. This integrated set of tools is referred to as the Aerodynamic Shape Optimization (ASO) Library. The tools consisted of flow solvers, grid-generation and perturbation tools, design variable and geometric constraint implementation tools, gradient computation methods, and numerical optimization methods. Some of the tools were commercially available, others were developed in-house, and still others were modifications of commercial software.

Both single and multiple grid-block Euler optimization methods were developed and applied. The single-block method was used solely for the cruise-point design of wing-body-nacelle configurations, and the multi-block method was used for the multi-point designs of full configurations. Both optimization methods were coupled to constrained and unconstrained optimization algorithms, which employ sequential quadratic programming methods. These methods allow for a single objective function and multiple linear and nonlinear constraints. The objective function gradients are with respect to a user-specified set of design variables. The gradients are calculated using either finite differences or, more efficiently, with the adjoint method. The adjoint method results in over an order-of-magnitude reduction in computational time relative to the use of finite differences. Consequently, a much larger set of design variables can be employed with the adjoint approach. The single-block method was run exclusively on the CRAY C-90; the multi-block method was parallelized and run on a variety of platforms.

A number of analytical tools were used to provide higher fidelity analysis of the optimized configurations than provided by the design methods. Intermediate and final configuration analyses were carried out by use of the AIRPLANE Euler code and two Navier-Stokes codes. AIRPLANE uses an unstructured tetrahedral mesh and is therefore capable of computations about arbitrarily complex configurations. Navier-Stokes analyses were performed with OVERFLOW and UPS. OVERFLOW was used to analyze the wing/body/nacelle/diverter configurations, and UPS was restricted to wing/body configurations. The UPS code uses an upwind marching scheme and was used to validate previous Ames HSR designs; it was found to produce very accurate solutions.

The TCA baseline configuration, which was the subject of the optimization effort and is shown in the figure, was developed by the Boeing Company in support of the NASA HSR program, using linear-theory-based methods and extensive multidisciplinary system analysis. The design was subject to an extensive set of geometric constraints generated as part of the conceptual design of the aircraft.

The configuration consisted of a wing, body, four nacelles and boundary-layer diverters for the single cruise-point (Mach 2.4) design. For the multi-point design, the configuration was expanded to include leading and trailing edge wing flaps for improving transonic performance and a canard and empennage for longitudinal trim. Multi-point optimization was performed at three design points: supersonic cruise, transonic cruise, and transonic acceleration, corresponding to Mach 2.40, 0.90, and 1.10, respectively.

Cruise-point optimization using the single-block approach was followed by two forms of multi-point design: (1) sequential design (design at the cruise-flight condition followed by flap and canard/tail incidence angle optimization at the two transonic

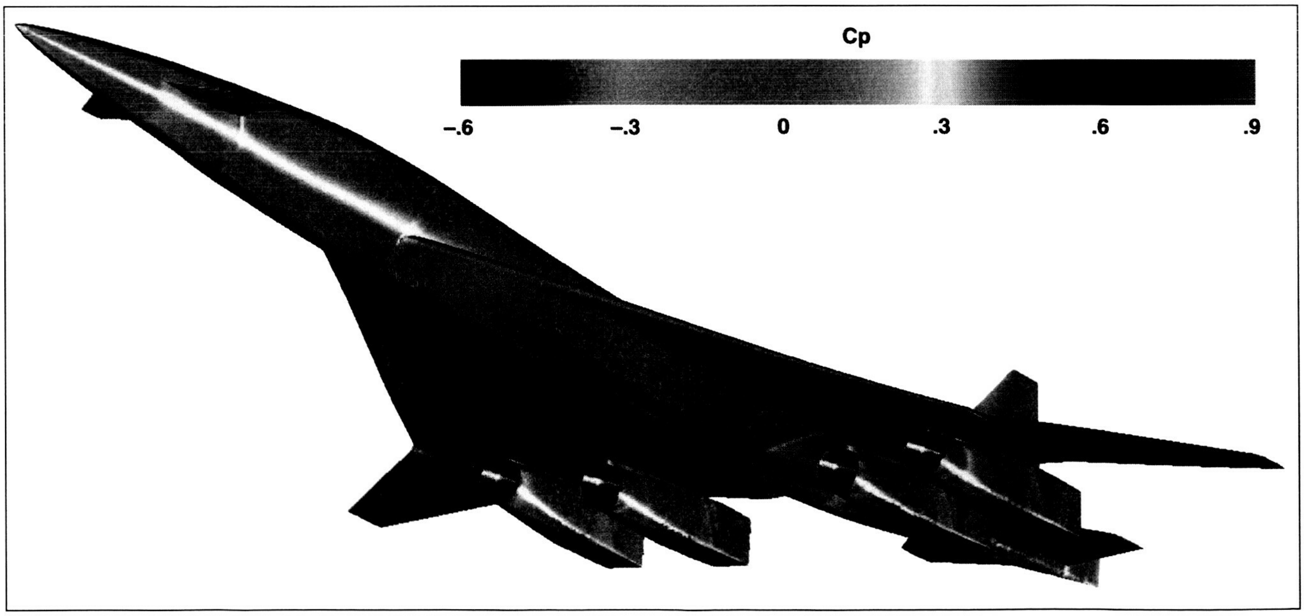

Fig. 1. AIRPLANE computation of the TCA configuration at the transonic acceleration design condition, M = 1.1, angle of attack = 3.5 degrees.

conditions), and (2) multi-point design (simultaneous design at the three flight conditions via a composite objective function). The single-point approach produced the bulk of the performance benefits, lowering the weighted-composite required thrust by 4.28 counts after trimming the full configuration at the three design points. (A 7.0 count drag reduction was achieved at cruise for the vehicle without trimming surfaces.) The sequential and multi-point methods achieved 6.03 and 7.55 counts of thrust reduction, respectively. These performance gains are significant, since a single drag count reduction at cruise reduces the takeoff weight of current designs by approximately 8,000 pounds.

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Resound Microphone Wind Noise Reduction

Clifton Horne, Paul T. Soderman

ReSound Corp. in Redwood City, California, has developed a miniature, ear-mounted, hands-free, microphone/receiver for use by technicians, police, firefighters, or others who need an unobtrusive communication system. When used in the field, however, wind-induced noise tended to mask voice communication. A foam covering reduced the noise, but was bulky and obtrusive. Through a Reimbursable Space Act Agreement, ReSound collaborated with the Experimental Physics Branch personnel to mitigate the wind-induced noise without resorting to bulky foam coverings.

To achieve the objective, an artificial head was installed in a ducted fan flow in the AIP acoustics laboratory (figure 1), and a series of experiments was conducted on wind-induced noise of the baseline ReSound microphone over a 3-month period. Using technology developed at Ames for measurement of aircraft model noise in wind tunnels, a screen-covered forebody was designed that protected the microphone sensor yet conformed to the shape and size of the ear-mounted device (figure 2). The forebody had an aerodynamic shape to minimize flow perturbations; the screen inhibited unsteady pressures at the sensors while passing sound waves. New information was acquired on the baseline and on improved microphone designs regarding effects of turbulence, wind speed, head-tilt angle, and yaw angle. The fluid-mechanic sources of wind noise were isolated. Turbulence, airspeed, and noise were measured in the fan flow, in the free-wind outdoors, in a moving truck in calm air, and in the low turbulence 7- by 10-foot wind tunnel. Results showed that the new wind screen gave improved noise reduction

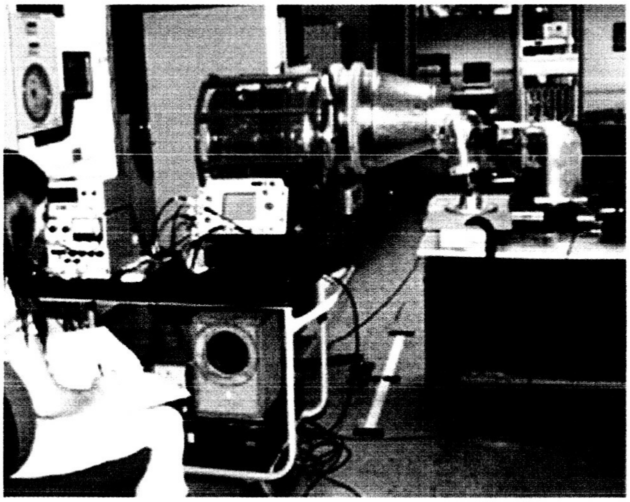

Fig. 1. Experimental set-up in acoustic lab with artificial head model, wind simulator, and instrumentation for measuring flow characteristics and microphone noise.

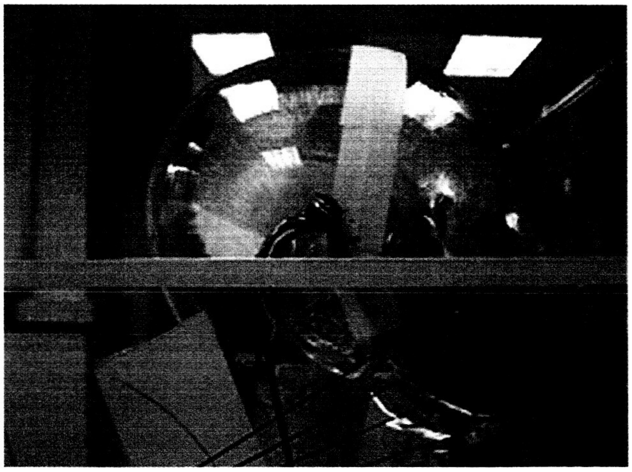

Fig. 2. Close-up detail of artificial head model with ear-mounted microphone and alignment template.